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Tannin content affects negatively nutritive value of pea for monogastrics *

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ABSTRACT

Nine Polish varieties of pea (*P. sativum* L.) differing in flower colour, from white to purple, were evaluated for chemical and amino acid composition and *in vitro* for predicted ileal digestibility of protein (pdN) and predicted digestibility of energy (pdE) for pigs. In selected varieties differing in tannin content the apparent metabolizable energy value corrected for zero N balance (AME_N), apparent digestibility of protein and fat and effect of enzymes reducing viscosity of digesta on this parameters were estimated in chickens; apparent metabolizable energy value (AME), true digestibility and biological value of protein was determined in rats.

Tannin content had most pronounced negative effect on protein digestibility in chicken ($r= -0.93$; $P<0.05$) and rats ($r= -0.89$; $P<0.05$), pdN for pigs ($r= -0.98$; $P<0.001$) as well as AME_N for chicken ($r= -0.99$; $P<0.001$) and AME for rats ($r= -0.95$; $P<0.01$), while nutrient content in peas had no significant effect on measured parameters. AME_N values of pea did not depend on supplementation of pea-containing diet with xylanase.

Seeds of coloured-flowered cultivars, which are rich in tannins are less effectively utilized by monogastric animals than white-flowered ones. The degree of decline in nutrient utilization depends on tannin content in the seeds, which is correlated with the colour of the flowers.

KEY WORDS: *Pisum sativum*, tannins, chickens, rats, energy value, protein value

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INTRODUCTION

An importance of pea as a component of feed mixtures for poultry and pigs recently increased, as pea protein may substitute part of meat meal protein, withdrawn from animal diets for sanitary reasons. Pea production increased considerably in Europe and many research programmes were established to study the composition of different types and cultivars of pea and relationships between composition criteria and nutritional value of pea (Bastianelli et al., 1998; Grosjean et al., 1998a,b, 1999). In Poland, among seventeen registered cultivars of pea grown on light soils, twelve (Wiatr, 1999) belongs to a colour-flowered (*P. sativum* L. ssp. *arvense*), yielding seeds with higher tannin content than white-flowered varieties (*P. sativum* L. ssp. *sativum*). Tannins are recognized as a main antinutrient in colour-flowered field beans and peas (Savage, 1989). Comparison of chemical composition and ileal digestibility of amino acids for pigs of 10 Polish cultivars of pea was done by Gdala et al. (1992), the content of nutrients and antinutritional substances in 15 cultivars of white-flowered pea was determined by Zduńczyk et al. (1997).

The objective of the present study was to compare the composition and nutritional value of peas differing in flowers colour and tannin content in seeds, and to assess effects of feeding them on selected parameters of gastro-intestinal functions in chicken and rats. In experiment with chicken the effects of supplementation of pea diets with xylanase were also determined.

MATERIAL AND METHODS

Seeds (sowing grade) of 9 Polish cultivars of spring pea from 1998 harvest year were obtained from plant breeding stations and comprised the white-flowered: Mazurek, Albatros, Agra, Piast, the red-flowered: Bart, Idol, Dawo, Wiato and the purple-flowered Żuraw.

In vivo tests

The experiments were complied with obligatory ethical regulations concerning animal experimentation and care of animals under study.

Experiments on chickens. Seeds of 5 cultivars differing in tannin content - Albatros, Piast, Idol, Wiato and Żuraw were used. Experiment was done on 98 four-week-old broiler chickens (Cobb 500) with a mean initial body weight of 1032 g. The birds were housed individually in balance cages, 8 (test groups) or 9 (control groups) birds per treatment. Two control groups were fed basal diets (A or B) containing (in g/kg): wheat, 590; soyabean oil meal, 334; rape seed oil, 3; mineral-vitamin mixture, 4.4; L-lysine, 0.1 and DL-methionine, 0.1. Diet A was not supplemented, while diet B was supplemented with 1 g of enzyme preparation Bio-Feed Wheat CT (Novo Nordisk) containing 1000 FXU xylanase/g according to producer. Remaining groups were fed test diets composed of basal diet A or B and ground pea combined in proportions as 1:1 on DM basis. To the basal and test diets 3 g Cr_2O_3 per kg DM was added as a marker. All diets were cold pelleted.

The diets were fed at the level of 100 g/bird/day, in three meals. After 2 days of preliminary feeding the birds were fasted during 17 h then fed on the same diets for 4 days, and fasted for 17 h. Feed intake was recorded and excreta was collected during last 96 h of the experiment. Excreta were immediately frozen and kept at - 18°C for further analysis. Apparent metabolizable energy value corrected for zero N balance (AME_N), apparent digestibility of protein, fat and organic matter retention was calculated for basal and test diets. Respective values for evaluated cultivars of pea were calculated by difference method according to Campbell et al. (1983) and Pesti and Ware (1986), the values obtained for basal diets A or B were used as a reference.

At the end of the experiment all birds were killed by decapitation, digestive tract was removed, small intestine was ligated to avoid the post-mortem movement of digesta, and intestinal contents were withdrawn by gently finger stripping. The jejunal digesta were collected to tubes placed on ice, centrifuged at 10000 x g for 10 min, the supernatants were withdrawn and their viscosity determined using a Brookfield digital viscometer (Model DV-II +LV) maintained at 40°C. The ileal digesta from two birds was pooled, mixed with distilled water 1:1 w/w and pH was immediately measured on WTW 340 A digital pH-meter.

Experiments on rats. Seeds of 6 cultivars differing in tannin content: Albatros, Piast, Idol, Dawo, Wiato and Żuraw were used in two experiments. In experiment 1 true digestibility (TD) and biological value (BV) of protein was determined by the Thomas-Mitchell method according to the procedure described by Smulikowska et al. (1997). Semisynthetic diets contained ground pea as the only source of protein at a level corresponding to 95 g crude protein per kg. Each diet was fed to eight four-week old male IF_Z:JAZ rats, with mean initial body weight 79 g. Net protein utilization (NPU = BV x TD) and utilizable protein content (NPV = NPU x CP, %) were calculated.

In experiment 2 apparent metabolizable energy value (AME) was measured on six-weeks old male IF_Z:JAZ rats, with mean initial body weight of 101 g. Basal diet was composed of (in g/kg): cereals, 618; soyabean oil meal, 150; fish meal, 80; milk powder, 100; soya oil, 20; mineral-vitamin mixture, 32. Test diets contained per kg: 400 g of basal diet and 600 g of ground pea. Basal diet was fed to 14 rats, test diets were fed to 8 rats each in amount 13-15 g per day. After 4 days of preliminary period faeces were collected quantitatively for 6 days. The faeces were kept at -18°C for further analysis. AME of the peas was calculated by the difference method using the values obtained for basal diet as a reference. At the end of experiment rats were killed by CO_2 overdosing, the pancreas and caecum were dissected, caecal digesta were collected, the weight of pancreas, full and empty caecum and pH of caecal contents were measured.

In vitro tests

In all nine cultivars of pea seeds predicted apparent ileal digestibility of protein for pigs (pdN) was evaluated by *in vitro* method according to Boisen and Fernandez (1995), and predicted total tract digestibility of energy for pigs (pdE) by *in vitro* method according to Boisen and Fernandez (1997).

Chemical and statistical analysis

Weight of thousand seeds was determined, representative samples of seeds were dehulled and the percentage of hulls was calculated. Chemical composition of the seeds was determined according to AOAC (1990), neutral-detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) content according to Van Soest and Wine (1967) and Van Soest (1973) on a Fibertec M (Tecator) apparatus. Amino acids analysis of protein was performed with an automatic Beckman 6300 High Pressure Amino Acid Analyzer after acid hydrolysis. Methionine and cystine were determined after oxidation with performic acid and tryptophane after hydrolysis with BaOH according to Buraczewska and Buraczewski (1981). Trypsin inhibitor activity was analyzed according to Kakade et al. (1974). Tannin content in pea seeds and hulls was evaluated according to the method of Jerumanis (1972) modified by Adams and Novellie (1975). Excreta of chickens prior to analysis were dried in a forced-draft oven at 70°C for 24 h. Chemical composition of diets and excreta was determined according to AOAC (1990), fat in chickens diets and excreta was extracted with diethyl ether after acid hydrolysis. Gross energy was determined by Parr adiabatic oxygen bomb calorimeter KL-10. Chromic oxide in diets and excreta was analyzed spectrophotometrically following wet ashing according to Hinsberg et al. (1953). Faecal N in excreta of chickens was determined according to Ekman et al. (1949).

Statistical evaluation of results was done by Statgraphic plus ver. 7 Software.

RESULTS

The seeds of white-flowered varieties were on average bigger than those of coloured-flowered ones, however in both types there were cultivars with small and big seeds. The white-flowered cultivars had on average lower percentage of seed coat and lower content of dietary fibre than the coloured-flowered cultivars (Table 1). The content of protein and starch was higher in white-flowered cultivars, but there were no distinct differences in the content of other nutrients between both types of pea (Table 2). Lysine content in 8 cultivars averaged 7.46, only in the Agra cv. was below 7 g/16 g N. Methionine and cystine content was on average 0.96 and 1.49 g/16 g N, respectively. There were no big differences in remaining amino acid content between cultivars (Table 3). Trypsin inhibitor activity was low (from 0.96 to 2.37 TIU/mg DM) and did not differ significantly between white- and coloured-flowered cultivars. Tannin content in white-flowered cultivars was very low and uniform (0.25 g/kg DM on average), in coloured-flowered significantly higher (7.26-12.1 g/kg DM). Most of tannins were present in seed coat (Table 2). Proportion of seed coat in coloured-flowered cultivars was bigger than in white-flowered and there was significant positive correlation between tannin content and percentage of hulls in seeds ($r=0.96$; $P<0.01$).

In chickens apparent protein digestibility differed significantly between white- and coloured-flowered cultivars, but apparent fat digestibility was significantly lower only for Żuraw cv. The AME_N value for chicken and metabolizability of energy of white-flowered peas was on average 12.86 MJ/kg DM and 64.5%, and differed from the values of coloured-flowered peas which were significantly

TABLE 1

Seed dimensions, percentage of hulls in seeds and fibre fraction content in seeds, g/kg DM

Pea cultivar	Weight 1000 seeds g	% hulls in seeds	Crude fibre	NDF	ADF	ADL	Dietary fibre[1]
White-flowered (WF)							
Mazurek	259	8.94	70	150	97	5.1	185
Albatros	287	8.16	66	152	90	5.0	191
Agra	192	8.92	69	169	95	3.7	183
Piast	282	7.61	59	126	78	4.2	186
Average (WF)	255	8.41	66	149	90	4.5	186
Coloured-flowered (CF)							
Bart	255	10.32	75	172	98	7.4	230
Idol	195	10.53	69	164	95	7.3	181
Dawo	300	9.75	61	169	93	6.5	213
Wiato	211	9.63	66	149	90	6.1	199
Żuraw	193	10.64	67	160	92	7.0	207
Average (CF)	240	10.17	68	163	94	6.9	206

[1] calculated as: DF = 100 - crude protein - ash - fat - starch - sugars

TABLE 2

Chemical composition of peas and tannin content, g/kg DM, and trypsin inhibitor activity, TIU/mg DM

Pea cultivar	Dry matter	Crude protein	Crude ash	Ether extract	Sugars	Starch	Tannins in seeds	Tannins in hulls	TIU
White-flowered (WF)									
Mazurek	885	240	34	11	457	73	0.27	0.35	1.97
Albatros	884	237	32	9	461	70	0.22	0.37	0.96
Agra	893	229	35	14	493	46	0.27	0.34	2.33
Piast	878	205	34	16	495	64	0.23	0.30	2.06
Average (WF)	885	228	34	12	476	63	0.25	0.34	1.83
Coloured-flowered (CF)									
Bart	891	210	33	14	442	71	7.76	80.9	1.61
Idol	888	218	29	11	493	68	8.49	81.3	1.94
Dawo	884	194	30	12	489	62	7.26	72.3	2.32
Wiato	885	225	32	11	468	65	7.92	83.8	2.37
Żuraw	878	238	34	12	445	64	12.11	103.7	1.89
Average (CF)	885	217	32	12	467	66	8.71	84.4	2.03

TABLE 3

Amino acid composition of pea protein, g/16 g N

Amino acid	Pea variety								
	white-flowered				coloured-flowered				
	Mazurek	Albatros	Agra	Piast	Bart	Idol	Dawo	Wiato	Żuraw
Lys	7.36	7.40	6.93	7.56	7.54	7.42	7.59	7.48	7.36
Met	0.92	0.92	1.02	1.02	0.99	0.96	0.97	0.95	0.91
Cys	1.45	1.27	1.60	1.64	1.50	1.46	1.55	1.49	1.48
Thr	3.83	3.95	3.70	3.96	4.06	3.93	4.02	3.84	3.77
Trp	0.91	0.95	0.98	0.96	0.97	0.96	0.96	0.94	0.92
Ile	4.23	4.17	3.96	4.33	4.34	4.23	4.30	4.25	4.20
Val	4.82	4.79	4.66	5.12	4.91	4.86	4.83	4.82	4.76
Leu	7.37	7.40	6.86	7.60	7.64	7.38	7.54	7.47	7.33
Tyr	3.28	3.18	3.17	3.30	3.27	3.35	3.29	3.30	3.22
Phe	4.91	4.85	4.65	4.95	5.09	4.96	5.08	5.01	4.95
His	2.47	2.48	2.39	2.68	2.48	2.51	2.44	2.49	2.49
Arg	8.69	9.46	8.54	8.87	7.96	8.63	7.88	8.73	9.05
Asp	12.18	12.40	11.01	12.20	11.84	12.11	12.10	12.18	12.28
Ser	4.78	4.97	4.66	5.01	4.90	4.82	4.93	4.84	4.87
Glu	17.55	17.31	16.44	17.69	17.04	17.23	17.13	17.26	17.55
Pro	4.00	3.97	4.03	4.20	4.04	4.04	4.04	4.09	4.03
Gly	4.34	4.35	4.42	4.68	4.51	4.44	4.48	4.39	4.37
Ala	4.31	4.36	4.25	4.53	4.52	4.38	4.44	4.32	4.26

(P<0.05) lower: 12.27 MJ/kg DM and 61.5% respectively (Table 4). Inclusion 50% of pea into diet did not affect significantly the viscosity of jejunal digesta or pH of ileal digesta in chickens (Table 4). Enzyme supplementation of basal diet lowered significantly the viscosity of jejunal digesta by about 30% and pH

TABLE 4

Apparent digestibility of crude protein (CPD) and crude fat (CFD), organic matter retention (OMR) and metabolizable energy (AME_N) of basal diets and pea cvs[1], viscosity of jejunal digesta and pH of ileal digesta in chickens

Pea cv and type of basal diet	CPD %	CFD %	OMR %	AME_N MJ/kg DM	Viscosity of jejunal digesta, cP	pH of ileal digesta
Basal (A)	89.4	78.6	71.9	13.94	2.27	7.75
Basal (B)	90.0	80.7^{X}	72.4	14.13^{X}	1.62^{X}	7.29
Albatros (A)	87.8	62.3	63.2	12.72	2.36	7.46
Albatros (B)	88.1	68.9	66.7	12.91	1.93	7.78
Piast (A)	83.5	60.9	68.3	12.94	2.48	7.44
Piast (B)	83.4	62.0	67.5	12.88	1.84	7.70
Idol (A)	79.6	62.1	64.7	12.53	2.56	7.80
Idol (B)	80.7	66.3	63.1	12.21	1.95	7.49
Wiato (A)	78.3	65.9	65.2	12.30	2.43	7.46
Wiato (B)	77.2	62.2	65.8	12.39	1.62	7.59
Żuraw (A)	73.9	55.3	61.0	11.99	2.39	7.72
Żuraw (B)	75.5	56.0	64.2	12.22	1.95	7.81
SEM	0.56	2.14	0.80	0.14	0.21	0.13
Source of variation				Probability		
Cultivar	0.001	0.001	0.001	0.001	0.845	0.421
Enzyme	0.347	0.522	0.070	0.787	0.001^{2}	0.243
Enzyme x cv	0.147	0.093	0.004	0.277	0.869	0.155
				Means of pea cultivars		
Albatros [W]	88.0^{a}	65.7^{aA}	65.0^{b}	12.82^{bBC}	2.14	7.62
Piast [W]	83.5^{b}	61.5^{abAB}	67.9^{a}	12.91^{bC}	2.16	7.57
Idol [R]	80.1^{c}	64.2^{aA}	63.9^{bc}	12.37^{aAB}	2.26	7.64
Wiato [R]	77.8^{d}	63.9^{aA}	65.5^{b}	12.35^{aAB}	2.02	7.53
Żuraw [P]	74.7^{e}	55.7^{bB}	62.6^{c}	12.10^{aA}	2.17	7.77

[W] white; [R] red; [P] - purple-flowered; [1]values of CPD, CFD, OMR and AME_N for pea cultivars were calculated by difference method with the use as a reference the values obtained for basal diets A or B

[X] values obtained for basal diet B significantly differs from diet A (P< 0.05); [abAB] means in columns with different superscripts are significantly different: [ab] at P<0.05; [AB] at P<0.01

[2] mean viscosity for groups fed diets without enzymes was 2.44; for groups fed diets supplemented with enzyme 1.86 cP

of ileal digesta by 5%; fat digestibility and AME_N value of basal diet increased significantly (P<0.05), but apparent protein digestibility and organic matter retention was not affected. Enzyme supplementation of test diets also significantly lowered viscosity of digesta by 24% on average, but did not affect significantly pH of jejunal digesta, AME_N value of peas or digestibility of their components (Table 4).

In rats the digestibility of protein of white-flowered peas was significantly higher than coloured-flowered cultivars (on average 85 vs 79.5%; P<0.05). In contrast the biological value of protein in 5 cultivars was similar and averaged 86, and only the BV of protein of the Idol cultivar was significantly higher (Table 5). The NPU value of the purple-flowered Żuraw cv. was significantly lower from white-flowered cv. Albatros and Piast and the red-flowered cv. Idol. The AME value for rats of white-flowered peas was on average 16 MJ/kg DM what means 1 to 2 MJ/kg higher than of coloured-flowered peas (P<0.05). After inclusion of red-flowered peas into diet, pH of caecal digesta was significantly (P<0.05) higher than on diets with white-flowered peas (Table 5).

Predicted values of ileal digestibility of protein and energy in pigs determined *in vitro* differed, pdN and pdE averaged respectively (in %): 86.2 and 85.4 for white-, 77.8 and 82.1 for red-, 73.5 and 77.4 for purple-flowered pea (Table 6).

DISCUSSION

The protein content in evaluated peas was lower than reported by Gdala et al. (1992) and Zduńczyk et al. (1997), but amino acid profile of protein agrees well with the values reported in both papers and with the mean values published by

TABLE 5

Indices of nutritional value of protein, metabolizable energy value of pea, pH of caecal digesta and weight of pancreas (g/100 g body weight) of rats fed diets with seeds of different pea cultivars

Pea cultivar	Protein digestibility (TD) %	Biological value of protein	Net protein utilization	Net protein value	AME MJ/kg DM	Weight of pancreas	pH of caecal digesta
Albatros ^{W}	84.4^{b}	85.1^{a}	75.2^{c}	17.8	15.93^{c}	0.494	5.82^{a}
Piast ^{W}	85.9^{b}	84.8^{a}	72.8^{bc}	14.9	16.11^{c}	0.503	5.77^{a}
Idol ^{R}	79.9^{a}	92.1^{b}	73.6^{bc}	16.0	13.96^{a}	-	-
Dawo ^{R}	78.6^{a}	88.9^{ab}	69.8^{ab}	13.5	15.07^{b}	0.507	6.14^{b}
Wiato ^{R}	79.6^{a}	86.9^{a}	69.2^{ab}	15.6	14.48^{ab}	0.550	6.16^{b}
Żuraw ^{P}	79.7^{a}	84.6^{a}	67.3^{a}	16.0	13.98^{a}	0.549	6.11^{b}
SEM	0.8	1.1	1.1	1.1	0.16	0.017	0.06

$^{W, R, P}$ as in Table 4; $^{a, b}$ – means in columns with different superscripts are significantly different at P<0.05

TABLE 6

In vitro ileal digestibility of protein (pdN) and total tract digestibility of energy (pdE) for pigs, %

Pea cultivar	pdN	pdE
Mazurek [W]	86.7	80.9
Albatros [W]	86.5	83.2
Agra [W]	85.9	89.4
Piast [W]	86.1	88.2
Bart [R]	77.6	86.2
Idol [R]	77.2	84.0
Dawo [R]	77.2	79.3
Wiato [R]	79.1	79.1
Żuraw [P]	73.6	77.4

[W, R, P] as in Table 4

WPSA (1992). The protein of evaluated cultivars had high lysine and low sulphur amino acid content. The lysine content in pea protein was about 45% higher than in meat meals, the sulphur-containing amino acids and threonine content was of the same order as in meat meals (WPSA, 1992). It makes pea a good substitute of meat meals in feed mixtures for growing chickens and pigs. In the context of meeting the dietary requirement of indispensable amino acids for poultry and pigs, cereal grains and peas are nutritionally complementary. The significantly higher biological value of protein of the Idol cv. could not be attributed to any difference in amino acid content. Mean trypsin inhibitor activity (TI) in all analyzed cultivars was 1.9 TIU/mg DM. The measured values were much lower and less variable than reported by Gdala et al. (1992), who found 5.1 in the white- and 8.9 TIU/mg DM in the coloured-flowered Polish cultivars from 1985-86 harvest years, and lower than reported by Zduńczyk et al. (1997). The last authors found 4 TIU/mg DM in white-flowered cultivars from 1992-1993 harvest year. Trypsin inhibitor activity in evaluated pea cultivars did not depend on the colour of flowers, similarly as in report of Bastianelli et al. (1998). It seems that Polish plant breeders succeeded in producing cultivars of pea of low activity of protease inhibitors. This means that one of the factors that may interfere with protein digestion in monogastric animals was nearly removed.

White-coloured cultivars were low in tannin, as was expected. Tannin content in coloured-flowered cultivars was higher, but within the limits reported by Gdala et al. (1992), Gdala and Buraczewska (1997) and Bastianelli et al. (1998). Statistical evaluation of results indicated, that of all determined components of pea seeds, tannins had the most pronounced negative effect on protein digestibility. Tannin content affected negatively protein digestibility in chicken ($r = -0.93$; $P < 0.05$) and rats ($r=-0.89$; $P<0.05$) and ileal digestibility of protein for pigs determined *in vitro* ($r = -0.98$; $P<0.001$). It agrees well with reports of other authors (Lindgren, 1975;

Gdala et al., 1992; Grosjean, 1999), who found significant differences in digestibility of protein between white- and coloured-flowered cultivars. The phenolic groups of tannins bind to enzymes and other proteins and form insoluble tannin-protein complexes resistant to digestive enzymes of monogastric animals, hydrogen bonds and hydrophobic interactions appear to be the principal linkages involved (Artz et al., 1987).

The BV of protein of evaluated cultivars was not correlated with tannin content, what indicates that tannins did not bind specifically with any limiting amino acid in pea protein. However NPV of evaluated cultivars depended less on the tannin content and was correlated negatively with trypsin inhibitor activity ($r = -0.84$; $P<0.05$). Due to relatively high protein content, the NPV of the Żuraw cv. was the same as NPV of the Idol cv. and higher than Piast cv. despite the differences in protein digestibility.

Metabolizable energy for chicken of white-flowered cultivars averaged 12.86, for coloured-flowered 12.27 MJ/kg DM and were in the range of the values obtained by Grosjean et al. (1999) on adult cockcrels (13.18 and 12.72 MJ/kg DM, respectively) and by Grosjean et al. (1998b) on broiler chickens (on average 12.24 MJ/kg DM for white-coloured tannin-free peas). The last authors noted considerable variability in metabolizable energy for broiler chicken of 26 analyzed pea batches (from 11.66 to 12.95 MJ/kg DM), but the correlation between chemical composition criteria and energy values were weak. Similarly in this study, nutrient and dietary fibre content had no significant effect on metabolizable energy value in evaluated cultivars, while tannin content affected negatively AME_N value for chicken ($r = -0.99$; $P<0.001$) and AME for rats ($r = -0.95$; $P<0.01$). Protein digestibility, AME_N values in chickens and AME in rats were also correlated with hulls content in seeds. Coloured-flowered varieties had proportionally more seed coat and higher tannin content, which are mostly present in the hulls.

In chickens due to substitution of half of the basal diet by pea, the viscosity of intestinal digesta increased slightly (on average by 7%). After supplementation of basal and test diets with xylanase the viscosity of digesta decreased significantly ($P<0.001$), but probably the dietary fibre of pea was resistant to the added enzyme, as the difference in viscosity between the basal and pea-containing groups extended (to 15% on average). Igbasan et al. (1997) found, that in the components of non-starch polysaccharides (NSP) of Canadian pea cultivars predominates glucose, followed by uronic acids, arabinose, xylose and galactose (on average 47, 22, 19, 6 and 4% of total NSP, respectively). The relatively high concentrations of uronic acids and arabinose residues indicate that pectic-type substances are important components of the cell wall of peas. The results of the present experiment proves that the effect of pectic substances of pea on viscosity of digesta in chicken may be neglected, as it did not affect the energy and protein values (Table 4).

Significantly higher pH values of caecal digesta in rats fed on colour-flowered pea (Table 5) indicates for an effect of tannins on caecal fermentation. Lower intensity of fermentation may result either from direct inhibitory effect of tannins on microflora or from greater amount of nondigested protein of dietary and endogenous origin reaching large intestine.

Predicted total tract digestibility of energy in pigs (pdE) averaged 85% for 4 white- and 2 cultivars of red-flowered pea, 79% for remaining 2 red-flowered cultivars and 77% for purple-flowered pea. PdE was not correlated with predicted ileal digestibility of protein (pdN), nor with tannin or nutrient content in seeds. Grosjean et al. (1998a) reported that apparent digestibility of energy in pigs was 89% for white- and 81% for coloured-flowered pea. The lower pdE value of the Żuraw cultivar was undoubtedly due to the high tannin content.

The lack of correlation of trypsin inhibitor activity with the relative weight of pancreas in rats confirms the results obtained on chickens, rats and in *in vitro* evaluation, that at the level present in evaluated cultivars trypsin inhibitors had not affected digestibility of protein. Al-Wesali et al. (1995) have demonstrated that *in vitro* purified trypsin inhibitor of pea had a far less inhibitory effect on casein digestibility than has soyabean trypsin inhibitor. However recently Hedemann et al. (1999) found, that in lines of pea which have 4-5 times more TI not only digestibility in rats, but also biological value of protein have been lowered in comparison with near-isogenic lines low in TI. It indicates, that trypsin inhibitor activity in new cultivars of pea should be continuously controlled.

The results indicate, that tannins present in colour-flowered pea may lower the digestibility of protein and metabolizability of energy in monogastric animals, while the role of dietary fibre and trypsin inhibitors in modern spring cultivars of pea is of smaller importance. However the amount of protein available to animals depends as well on the protein content in the seed. It seems that high protein content is the most important criterium of usefulness of pea in nutrition of monogastric animals nutrition but both the activity of TI and tannin content in new pea cultivars should be also monitored.

CONCLUSIONS

White flowered peas are digested better than coloured flowered peas. The digestibility is depressed by the presence of tannins. Lowering the tannin content should be included into breeding programs of new cultivars of pea, as the nutrients of high-tannin seeds are less effectively utilized by monogastric animals.

REFERENCES

Adams C.A., Novellie K., 1975. Composition and structure of protein bodies and spherosomes isolated from ungerminated seeds of Sorghum bicolor (Linn). Mun. Plant Physiol. 55, 1-6

Al-Wesali M., Lambert N., Welham T., Hedley C., Domoney C., 1995. Evaluation of pea seed trypsin inhibitors in *in vitro* protein digestibility studies. Proceedings of 2nd European Conference on Grain Legumes, Copenhagen (Denmark), pp. 290-291

AOAC, 1990. Official Methods of Analysis. Association of Official Analytical Chemists. 15th Edition. Washington, DC

Artz W.E., Bishop P.D., Dunker A.K., Schanus E.G., Swanson B.G., 1987. Interaction of synthetic proathocyanidin dimer and trimer with bovine serum albumin and purified bean globulin fraction G-1. J. Agr. Food Chem. 35, 417-421

Bastianelli D., Grosjean F., Peyronnet C., Duparque M., Regnier J. M., 1998. Feeding value of pea (*Pisum sativum*, L.) 1. Chemical composition of different categories of pea. Anim. Sci. 67, 609-619

Boisen S., Fernandez J. A., 1995. Prediction of the apparent ileal digestibility of protein and amino acids in feedstuffs and feed mixtures for pigs by in vitro analyses. Anim. Feed Sci. Tech. 51, 29-43

Boisen S., Fernandez J. A., 1997. Prediction of the total tract digestibility of energy in feedstuffs and pig diet by in vitro analyses Anim. Feed Sci. Tech. 68, 277-286

Buraczewska L., Buraczewski S., 1981. A note on determination of methionine and tryptophan. In: Proceedings of the 6th International Symposium on Amino Acids, Serock (Poland), pp. 47-50

Campbell G. L., Campbell L. D., Blair R., 1983. Calculation of metabolizable energy for ingredients incorporated at low levels into a reference diet. Poultry Sci. 62, 705-707

Ekman P., Emanuelson H., Fransson A., 1949. The digestibility of protein in poultry. Kungl. Lantbruks.-Hogskol. Ann.16, 749

Gdala J., Buraczewska L., Grala W., 1992. The chemical composition of different types and varieties of pea and the digestion of their protein in pigs. J. Anim. Feed Sci. 1, 71-79

Gdala J., Buraczewska L., 1997. Ileal digestibility of pea and faba bean carbohydrates in growing pigs. J. Anim. Feed Sci. 6, 235-245

Grosjean F., Barrier-Guillot B., Bastianelli D., Rudeaux F., Bourdillon A., Peyronnet C., 1999. Feeding value of three categories of pea (*Pisum sativum*, L.) for poultry. Anim. Sci. 69, 591-599

Grosjean F., Bastianelli D., Bourdillon A., Cerneau P., Jondreville C., Peyronnet C., 1998a. Feeding value of pea (*Pisum sativum*, L.) 2. Nutritional value in the pig. Anim. Sci. 67, 621-625

Grosjean F., Williatte-Hazouard I., Barrier-Guillot B., Skiba F., Metayer J. P., Peyronnet C., Gatel F., 1998b. Variability of energy value of pea for pigs and broiler chickens: Attempts to identify effects of environmental conditions and agricultural practices. Proceedings of 3rd European Conference on Grain Legumes, Valladolid (Spain), pp. 304-305

Hedemann M. S., Welham T., Boisen S., Canibe N., Bilham L., Demoney C., 1999. Studies on the biological responses of rats to seed trypsin inhibitors using near-isogenic lines of *Pisum sativum* L. (pea). J. Sci. Food Agr. 79, 1647-1653

Hinsberg K., Cremer H.D., Schmid G., 1953. In: Hoppe-Seyler/Thierfelder-Handbuch der Physiologisch-und Patologisch-Chemischen Analyse. Springer-Verlag, Vol. 5, 402-403

Igbasan F. A., Guenter W., Slominski B.A., 1997. Field peas: Chemical composition and energy and amino acid availabilities for poultry. Can. J. Anim. Sci. 77, 293-300

Jerumanis J., 1972. Űber die Veranderung der Polyphenole in Verlauf des Malzens und Maischens. Brauwissenschaft 25, 313-322

Kakade M. C., Rackis J. J., McGhee J. E., Puski G., 1974. Determination of trypsin inhibitor activity of soy products: collaborative analysis of an improved procedure. Cereal Chem. 51, 376-382

Lindgren E., 1975. The nutritive value of peas and field beans for hens. Swed. J. Agr. Res. 5, 159-161

Pesti G. M., Ware G. O., 1986. Expressing the variability in results of metabolizable energy assays. J. Nutr. 116, 1385-1389

Savage G. P., 1989. Antinutritive factors in peas. In: J. Huisman, T.F.B. van der Poel, I.E. Liener (Editors). Recent Advances of Research in Antinutritional Factors in Legume Seeds. Pudoc, Wageningen, pp. 342-350

Smulikowska S., Pastuszewska B., Mieczkowska A., Ochtabińska A., 1997. Chemical composition, energy value for chickens and protein utilization in rats of repeseed expeller cakes produced by different pressing technologies. J. Anim. Feed Sci. 6, 109-121

WPSA, 1992. European Amino Acid Table. W.M.M.A. Janssen, F.B.J.M. Ingelaat, Sj. Schaper, J. McNab (Editors). Publication of Working Group Nutrition, Beekbergen (The Netherlands)

Van Soest P.J., 1973. Collaborative study of acid detergent fiber and lignin. J. Assoc. Off. Anal. Chem. Int. 56, 781-782

Van Soest P.J., Wine R.H., 1967. Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. J. Assoc. Off. Agric. Chem. Int. 50, 50-55

Zduńczyk Z., Godycka I., Amarowicz R., 1997. Chemical composition and content of antinutritional factors in Polish cultivars of peas. Plant Food Hum. Nutr. 50, 37-45

Wiatr K., 1999. Pea. Results of cultivar testing (in Polish). COBORU (Editor). Słupia Wielka (Poland)

STRESZCZENIE

Taniny obniżają wartość odżywczą nasion grochu dla zwierząt monogastrycznych

W dziewięciu polskich odmianach grochu (*P. sativum* L.) różniących się barwą kwiatów, od białej do fioletowej, oznaczono skład chemiczny i skład aminokwasowy białka. Przewidywaną strawność białka (jelitowa, pdN) i energii (pdE) u świń oznaczono metodą *in vitro*. W 5 odmianach grochu, różniących się zawartością tanin, oznaczono u kurcząt brojlerów wartość pozornej energii metabolicznej (AME_N) oraz pozorną strawność białka i tłuszczu diet nieuzupełnionych lub uzupełnionych ksylanazą. Wartość energii metabolicznej (AME), strawność i wartość biologiczną białka 6 odmian grochu oznaczono na szczurach. Stwierdzono, że zawartość tanin w nasionach grochu była ujemnie skorelowana ze strawnością białka u kurcząt (r= -0,93; P<0,05), szczurów (r=-0,89; P<0,05) i świń (r= -0,98, P<0,001) oraz z wartością AME_N dla kurcząt (r=-0,99, P<0,001) i wartością AME dla szczurów (r=-0,95, P<0,01). Różnice w zawartości składników odżywczych między odmianami były niewielkie i nie wpływały w sposób istotny na mierzone wskaźniki wartości odżywczej nasion grochu. Uzupełnienie diety ksylanazą nie wpłynęło na wartość AME_N nasion grochu dla kurcząt.

Nasiona grochów kolorowo kwitnących są mniej efektywnie wykorzystywane przez zwierzęta monogastryczne niż nasiona odmian białokwitnących. Stopień obniżenia wykorzystania składników odżywczych grochu zależy od zawartości tanin, która jest skorelowana z barwą kwiatów.